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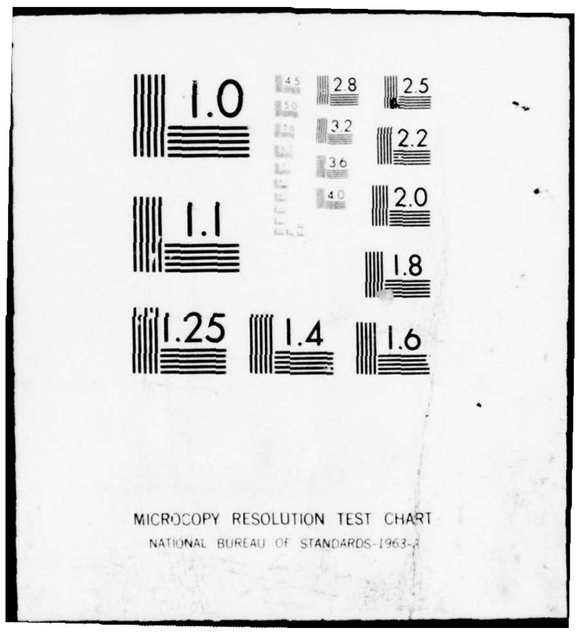
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(10) Mark Anthony Costa

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designed for the LVTP7 tracked amphibious personnel carrier, the vehicle presently in the U.S. Marine Corps inventory. The model was also adapted to defined design parameters of the Landing Vehicle Assault (LVA), the proposed successor to the LVTP7 tractor.

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An Examination of the Command, Control and
Communications System of a
U. S. Marine Corps Amphibious Assault Wave

by

Mark Anthony Costa
Captain, United States Marine Corps
B.S., United States Naval Academy, 1973

Submitted in partial fulfillment of the
requirement for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
June 1978

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This thesis examines the Command, Control and Communications procedures of an amphibious assault wave. The examination is preformed by the presentation of a model of the communication networks of a wave. Computer simulation results of the model are presented as an examination of the model's parameter sensitivity. Modifications and further extensions of the basic model are also discussed. The model presented was originally designed for the LVTP7 tracked amphibious personnel carrier, the vehicle presently in the U.S. Marine Corps inventory. The model was also adapted to defined design parameters of the Landing Vehicle Assault (LVA), the proposed successor to the LVTP7 tractor.

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I. INTRODUCTION

The ship-to-shore movement of the assault infantry elements of a Marine Amphibious Operation, is provided by the amphibian vehicles of the U.S. Marine Corps in a coordinated and disciplined sequence of landings. Command and control of this exercise is enhanced by experience and expertise gained through training and rehearsal. However, no matter how prepared the command structure may be, an open channel for command, control and communication is vital for success in all contingencies. The purpose of this thesis is to examine the command control and communication procedures of the U.S. Marine Corps amphibian vehicles in the ship-to-shore phase of an amphibian assault.

The examination of this subject will involve the present amphibian vehicle (LVTP7 Tractor) in the U.S. Marine Corps inventory, and the proposed vehicle design of the future (Landing Vehicle Assault, LVA). The LVTP7 tractor is a tracked vehicle using water jet propulsion in the waterborne mode to provide speeds of 6 to 8 miles per hour for the ship-to-shore transit. The LVA will also provide tracked vehicle capability ashore, but will be required to transit open seas in excess of 20 miles per hour.

The command, control and communication system is composed of the personnel, equipment, communication links and command relationships. A wave of amphibian vehicles

is a group of vehicles which transits ship-to-shore as a single unit and lands on their assigned beaches simultaneously. The wave is the smallest tactical unit in the amphibious assault, and is under the tactical command of a wave commander.

When describing a wave of vehicles, their responsibilities and their physical orientation to each other, the terms spacing and detection sector angle are used. Figure 1 illustrates these two terms. Spacing of the vehicles is measured in meters. Detection sector angle is measured in degree (Note that the detection sector angle is bisected by the center line of the vehicle).

The spacing of the vehicles in the wave defines lanes for each vehicle, a lane being one spacing in width. Each vehicle attempts to maintain position in the center of its lane. If a vehicle must maneuver within its lane to avoid an obstacle, then the vehicle requires a maneuver time. This time to maneuver is the time from the receipt and understanding of the order to maneuver, by the driver, to the instant the vehicle has completely responded by performing the required maneuver. The greatest maneuver time will be the time required for the vehicle to cease forward movement, that is, become dead in the water.

The chain of command within an assault wave consists of the wave commander, a crew chief for each vehicle and the vehicle drivers. The wave commander is responsible for

DEFINITION OF TERMS

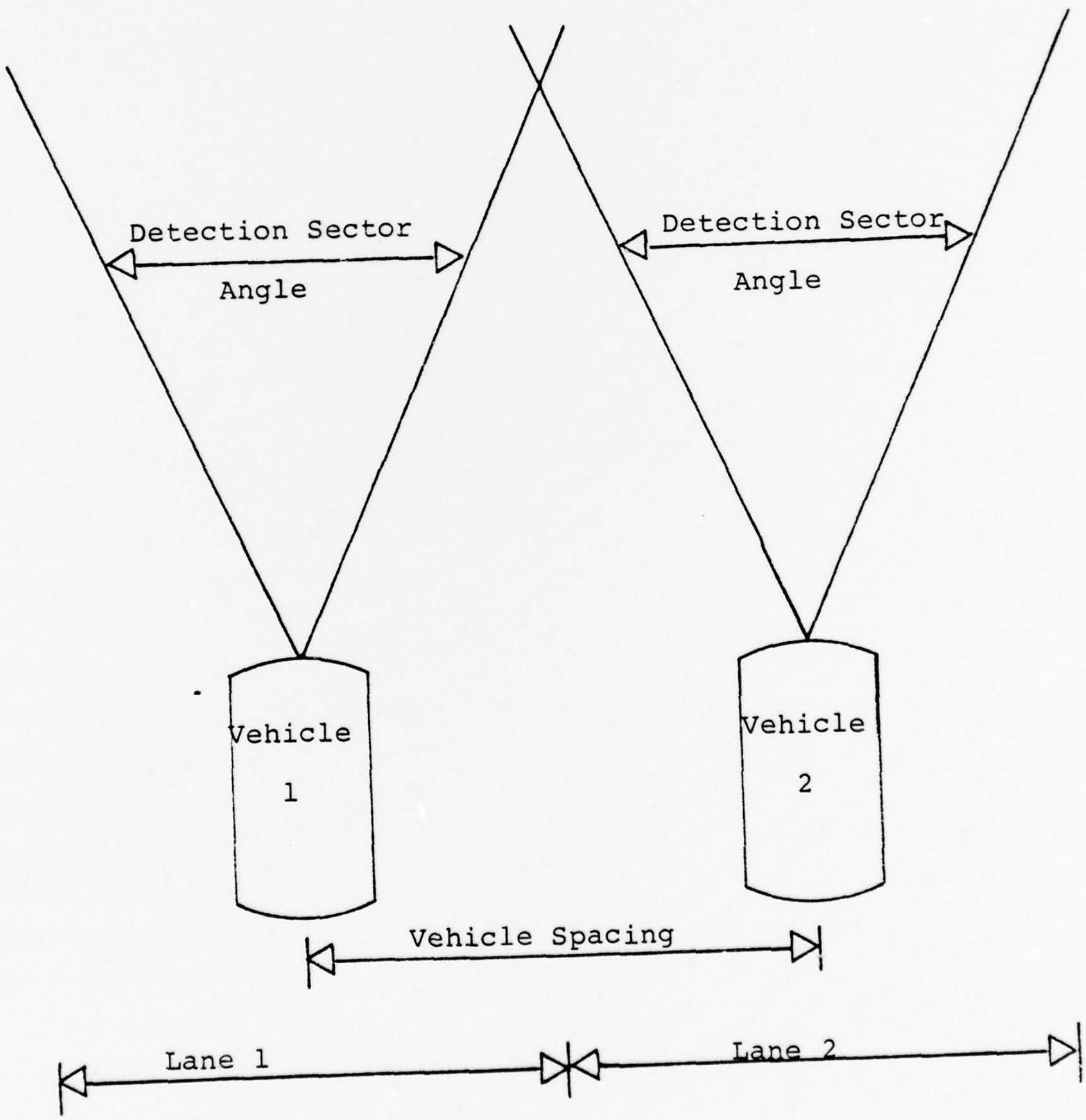

Figure 1

the movement of all vehicles in his wave from ship-to-shore and for their subsequent land operations. He is responsible primarily for the completion of his assigned mission and also for the health and safety of his crews and embarked personnel.

A crew chief is the individual responsible for the over-all operation of his vehicle, either waterborne or on land. He is responsible for his vehicle accomplishing its part of the wave's mission and for the health and safety of all embarked personnel. The crew chief consults the wave commander, when time permits, before executing individual maneuvers. However, the crew chief is responsible for the performance of his vehicle.

The vehicle driver is the individual whose actions affect the vehicle directly. The driver acts on directions from the crew chief, and in all cases requests directions when he detects a situation which he believes needs attention.

The command relationships, data inputs, response outputs, and links between the wave commander, a crew chief, and a vehicle driver are shown in Figure 2. From Figure 2 the communication links within the wave are readily apparent. Intercom communication exists between the driver and the crew chief of each vehicle. The wave commander and the crew chiefs communicate over the wave radio net, or by alternate means (eg. arm and hand signals). Communication

COMMAND RELATIONSHIPS AND
LINKS BETWEEN WAVE PERSONNEL

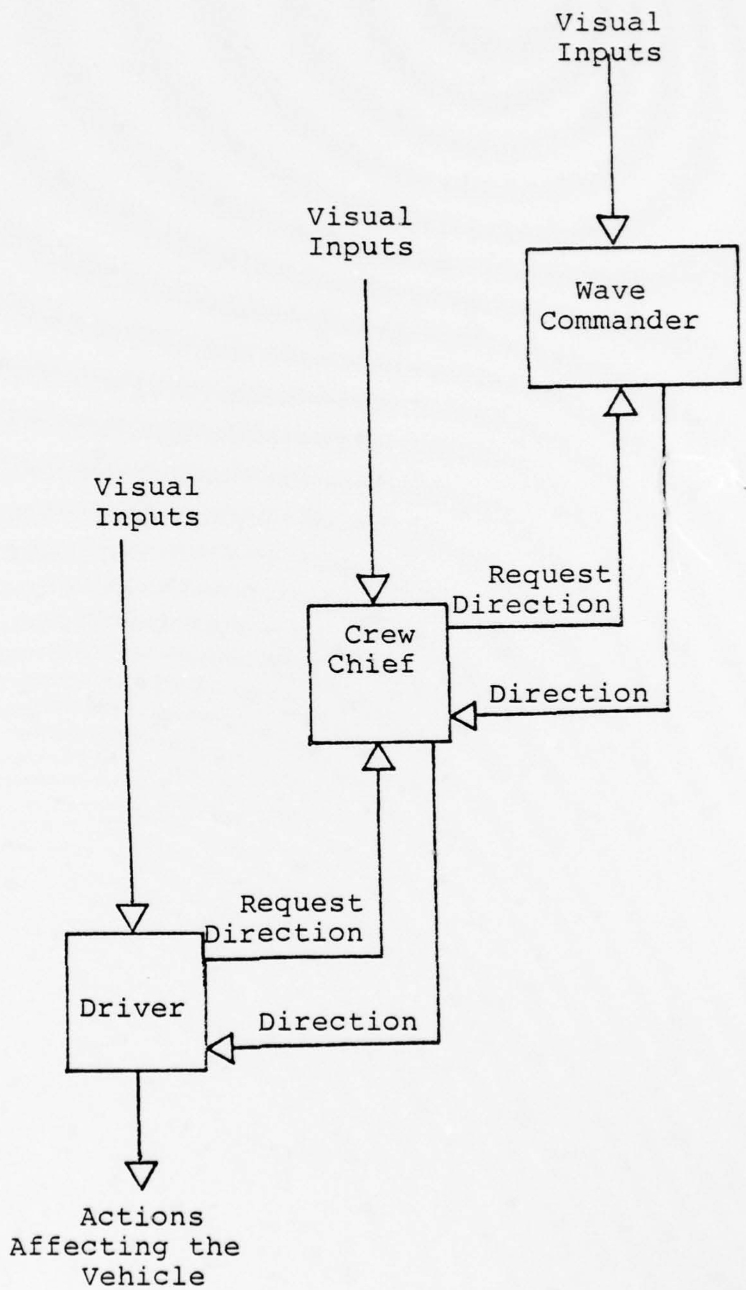

Figure 2

outside the wave is limited to the wave commander's monitoring of radio transmissions between the wave's guide boat (U.S. Navy) and the primary control ship. These naval vessels are responsible for guiding the wave to the line of departure, the point at which the assault begins.

The amphibious assault, although executed many times, has never been modeled with particular attention paid to the command, control and communications links. This thesis examines this topic by the construction of a model of the command, control and communications links of the ship-to-shore movement of a wave. The model was then exercised to identify those parameters which have a significant effect on the command and control of the wave. Finally, the model was exercised with different scenarios and system configurations to demonstrate the flexibility of the model.

II. THE MODEL

A network simulation was used to represent the command, control and communication links of the amphibian vehicle wave. A network format reflects the structure of a total system and its links in a transparent model. Nodes in this network represent individual personnel, pieces of equipment, and states (or conditions) the equipment or personnel may be in. Activities that connect nodes link personnel and equipment and provide the transit time to move from person-to-person, state-to-state, or from one piece of equipment to another. A simulation offers a possible glimpse of a real system from start to finish with the opportunity to exercise all alternatives. The simulation of this network provides a trace from a starting point in the command structure, through the communication links until all appropriate activities have been completed. Enhancing the attractiveness of this type of model was the availability of network solving algorithms by computer simulation.

A. SCOPE

An objective of this thesis was to provide a basic model from which expansion could be easily accomplished, and which was flexible enough to adapt to different vehicle characteristics, tactics and scenarios.

The wave, being the smallest tactical unit in the amphibious assault, was chosen as the scope of the model. A typical wave consists of ten vehicles. Since the on-line formation is always used in at least a portion of the ship-to-shore assault, that formation (physical relationship of vehicles to each other) is modeled in this thesis. In the on-line formation all ten vehicles travel abreast at a predetermined spacing. Finally, the communications and command structure modeled were restricted to include only the vehicles within the wave, that is intervehicle and intravehicle communication.

Various assumptions were made to provide generality and to facilitate use of the model. All vehicles and their inherent equipment were assumed to be homogeneous. Likewise, all like crew members of all vehicles were assumed to have equal ability and similar training. These assumptions provide a wave of ten identical vehicles with ten identical crews.

Key elements in the model are the times required to accomplish various tasks. In recognition of the random nature of these times, they were modeled as stochastic variables. The time between opportunities at which a vehicle's crew could detect an obstacle was assumed to be exponential. This assumption provides a glimpse model, with no memory of the last time the obstacle could have been detected. The length of a message to be transmitted

through the communication links was assumed to be uniformly distributed. These assumptions were made, purely to attempt to capture the randomness of the time required to communicate in the situation being modeled, and are not suggested to correspond to what happens in the real world. Additional operational testing is required to determine the actual distributions.

For the model of the LVTP7 tractor, the time required to maneuver was assumed to be normally distributed. This assumption was based on the test data from the Amphibian Vehicle Test Basin at Camp Pendleton, California. Since no prototype testing data was available for the proposed LVA, the time required to maneuver was taken to be uniformly distributed.

B. EXERCISING THE MODEL

To exercise the model the wave was confronted with a crisis situation. An obstacle was positioned in the path of the wave. The detection of the obstacle, communication of this detection, if necessary, and the maneuvering of the endangered vehicles, was presented as a simple test of the command, control and communications links.

An integral part of this exercise is the detection of the obstacle. In order to simulate detection of the obstacle, a detection model was constructed. The detection model used is similar to simplified detection models used

in land combat simulations. Since no data, as to the ability to detect obstacles in amphibian vehicles, while waterborne, was available this model was incorporated. The detection model used in the thesis is

$$\text{PROBABILITY OF DETECTION (Pdet)} = 1-\exp(-A/R^2),$$

Where A is a constant to be determined and R is the range of the obstacle at the time of possible detection. The range of the obstacle, R, is adjusted at each glimpse by the distance travelled at the closing speed during the time since the last glimpse. The time between glimpses was assumed to be an exponentially distributed random variable. Only those vehicles whose detection sector included the obstacle would have a glimpse of the obstacle. Once a probability of detection, Pdet, on a glimpse was determined, using the range of the obstacle from the vehicle, a random number was generated to simulate the outcome of the chance of detection. If the random number generated was less than Pdet, the probability of detection, the obstacle was detected by that vehicle at that time and range.

To set a threshold at which to base the detection model and evaluate the constant A, it was decided that the probability of detection, Pdet, given a glimpse, would be 0.15 at the maximum detection range. This provides a detection model of the form illustrated in Figure 3. Note that by varying the maximum detection range the probability of detection, given a glimpse at the same range, varies.

DETECTION MODEL
GRAPHICAL EXAMPLE

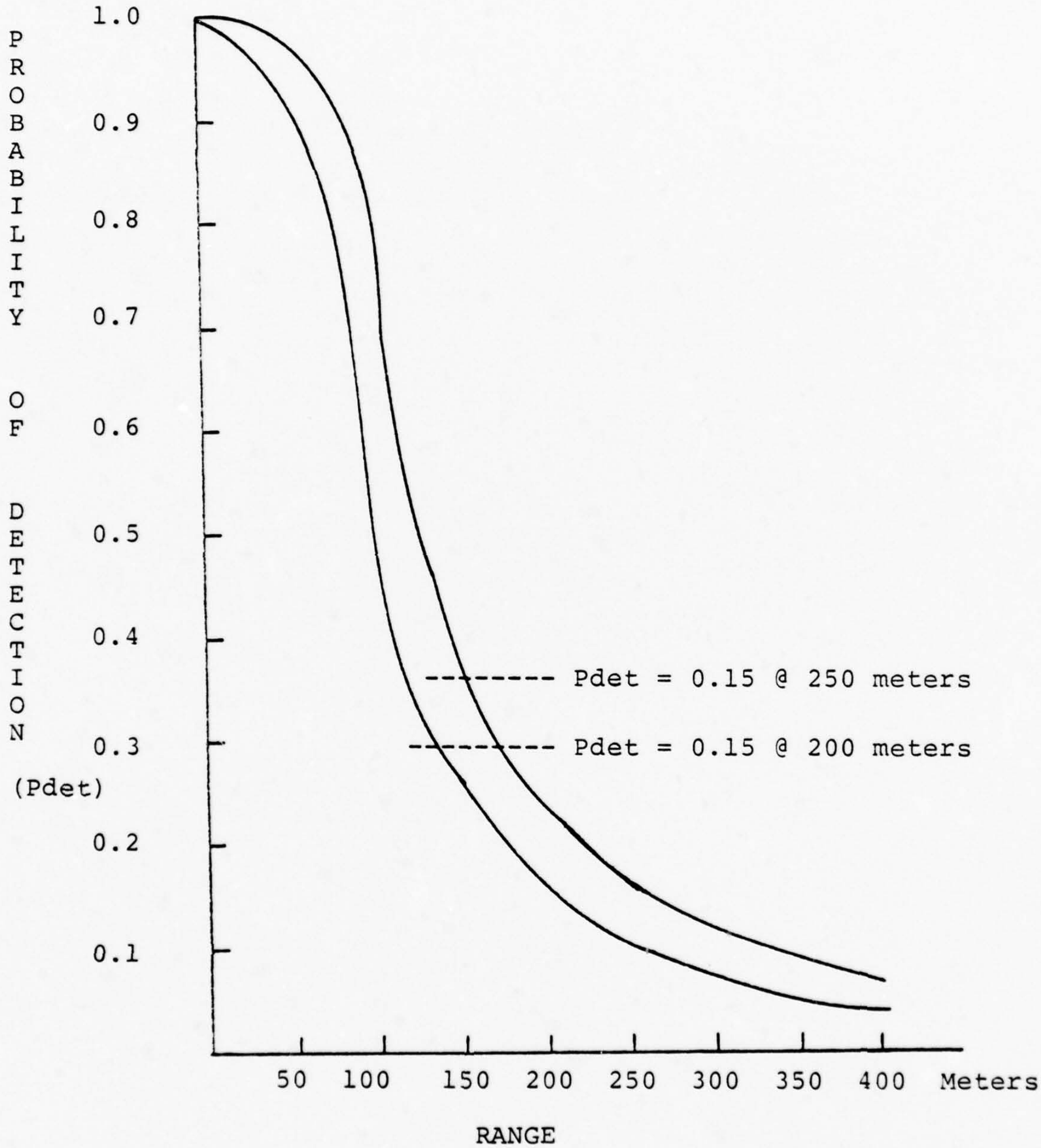

Figure 3

C. NETWORK MODELS

The first network constructed was the network consisting of the intercom and intravehicle communication between the crew chief and the driver. Figure 4 displays this communication subsystem with the individual communication devices labeled. Failures in particular links between devices were assumed to be random with probabilities of failure for each link as input parameters. If the intercom link is broken, an alternate voice communication link was modeled to represent physical movement of the crew chief to a position to speak directly and unaided, to the driver.

The next subsystem modeled was the communication by radio from one vehicle to another. It was assumed that the usage priorities of the radio receivers available in the LVTP7 tractor would be

1. The crew chief would monitor transmissions on his transmitter/receiver using antenna 1 until that circuit is inoperable.

2. The crew chief would monitor either of his two radio receivers (A or B) using antenna 2 when his primary circuit is inoperable.

This assumption is for simulation only. since the hardware configuration of the actual system enables the crew chief to monitor all three receiving devices simultaneously. Figure 5 shows the network of the intervehicle communication by radio. As in the case of the intercom, failures of

INTERCOM NETWORK
INTRAVEHICLE COMMUNICATION

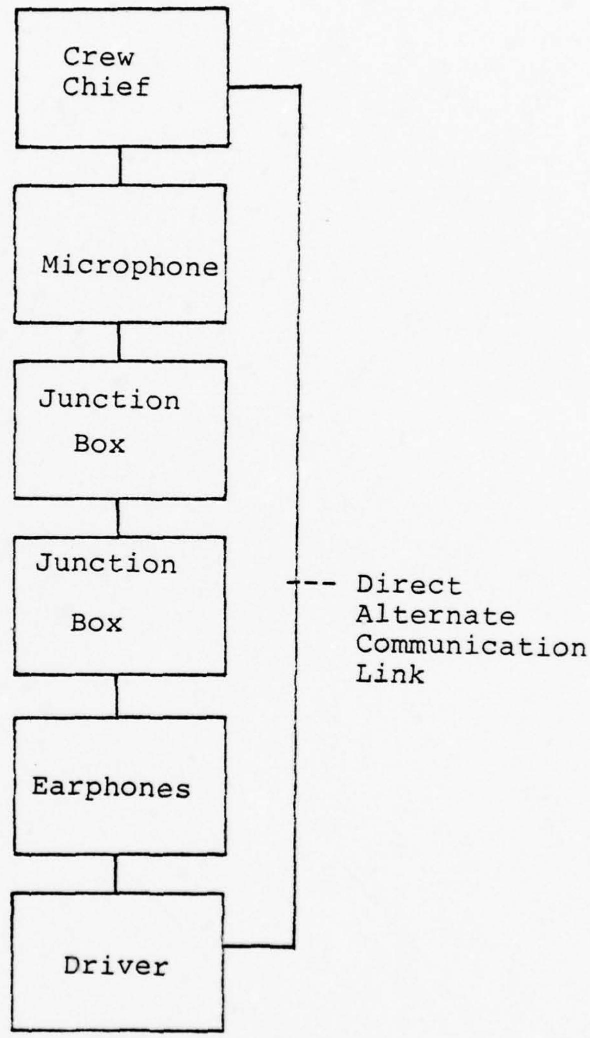

Figure 4

RADIO NETWORK
INTERVEHICLE COMMUNICATION

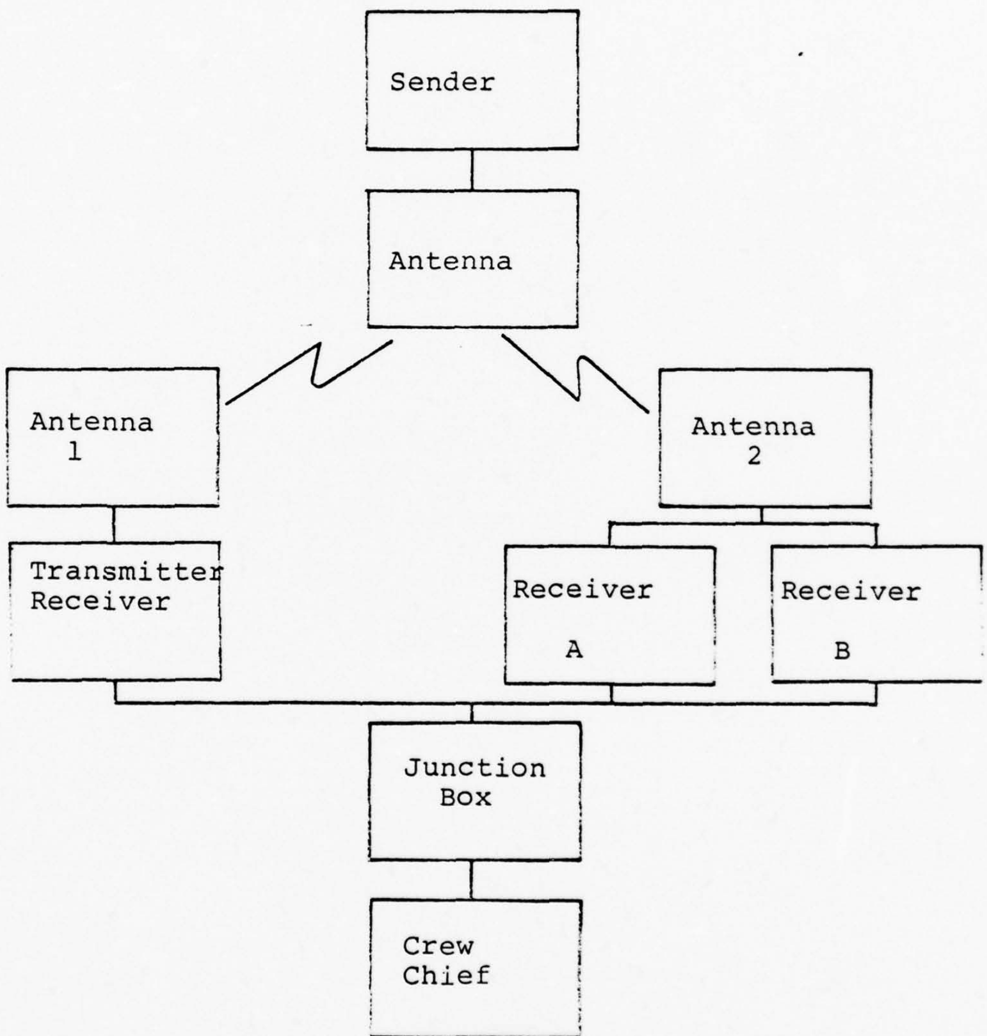

Figure 5

devices were assumed to be random with the probabilities of failure as input parameters for each device.

Finally the network of the wave of ten vehicles and their links was constructed. Figure 6 shows this network. It should be noted that it is assumed that once a vehicle detects an obstacle and determines it is not in his lane he continues to attempt to communicate to the endangered vehicle until he either communicates a warning or the obstacle reaches the wave. Both of these events cause the simulation to end. Appropriate modifications were made to the above three networks to make them adaptable for computer simulation and then the three networks were simulated.

TEN VEHICLE WAVE NETWORK

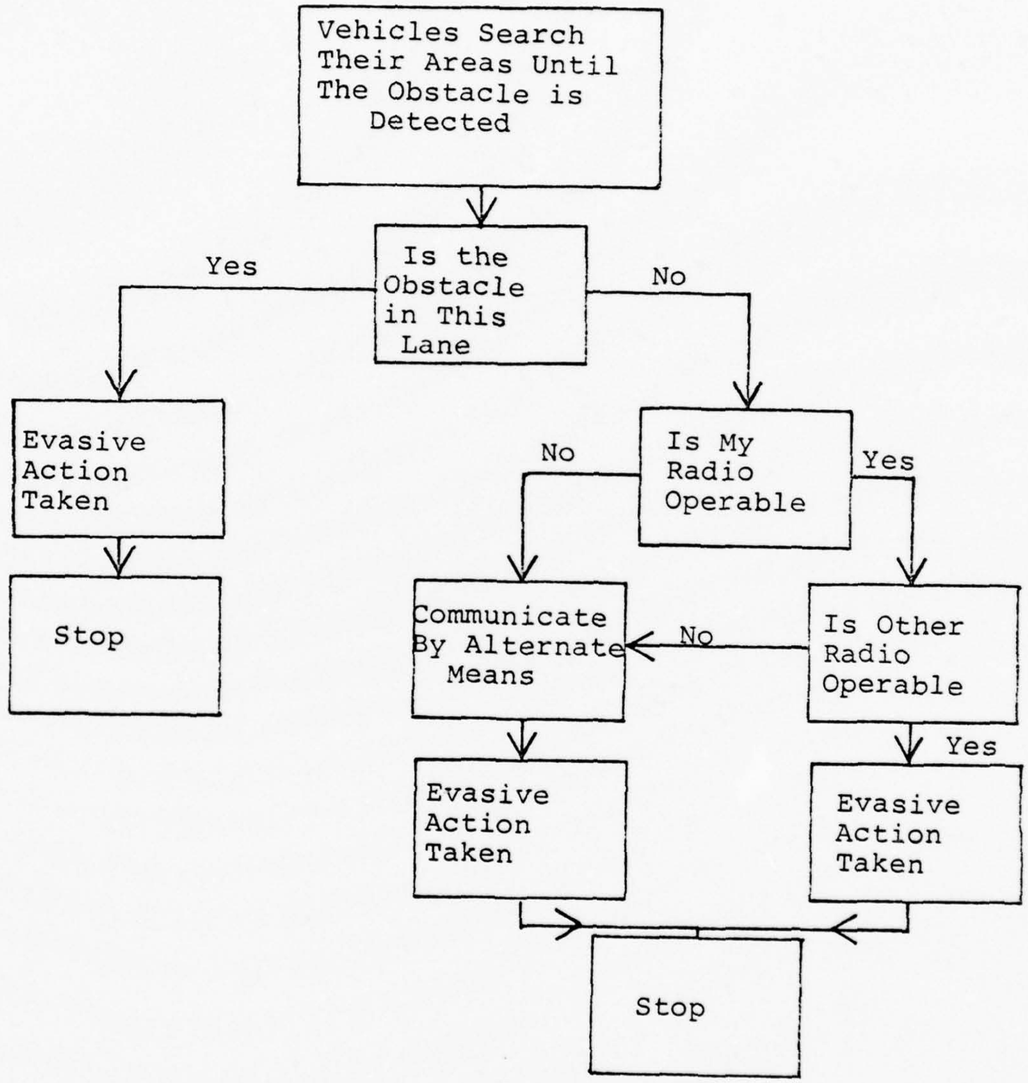

Figure 6

III. RESULTS OF MODEL SIMULATION

The computer simulation of the three networks was accomplished through the use of Q-GERT. This language was attrative due to its ability to accept the networks in data form. In Q-GERT each node and activity are entered as single sets of data. Also included in Q-GERT is the option to write user defined functions. These functions can perform logical branching or particular numerical calculations. Reference 1 was the guide used in implementing Q-GERT to simulate the networks. Appendix A contains a complete program for simulating the radio network for the LVTP7 tractor, written in Q-GERTS.

This chapter summarizes the results of the Q-GERT simulations for the three networks. In each case one thousand replications were run. This was done in an attempt to reduce the variance in the result of the simulation and to stabilize the estimates.

A. INTERCOM MODEL RESULTS

The simulation of the intravehicle communication first gave an estimate of the reliability of the intercom subsystem. This was done to show the ability of the network simulation to duplicate an analytical result, and to give a basic model capable of accepting future modification if the intercom subsystem changes. Figure 7 shows the network

and the random failure parameters used in the simulation. The analytical reliability equation of that network is

$$(0.95)\times(0.95)\times(0.95) = 0.857375 .$$

The results of the network simulation gave an overall reliability estimate of the intercom of 0.848. The length of a message was assumed uniformly distributed in time with a minimum message length of 8.0 seconds and a maximum of 12.0 seconds. It was found through simulation to take an average of 16.62 seconds, with variance 3.78, to get a message from the crew chief to the driver. As shown in Figure 7 the driver understands 90 percent of all messages he receives and requests a repeat of any message not understood.

B. RADIO NETWORK MODEL RESULTS

The Q-GERTS simulation of the radio network model supplied an estimate of the overall subsystem reliability. As in the case of the intercom network this simulation was performed, in part, to validate the network representation of an otherwise analytical reliability determination. But more importantly it was done to provide a basic network model of the radio communication between vehicles that could handle modifications that the analytic approach would find very difficult to solve.

INTRAVEHICLE COMMUNICATION
SIMULATION NETWORK

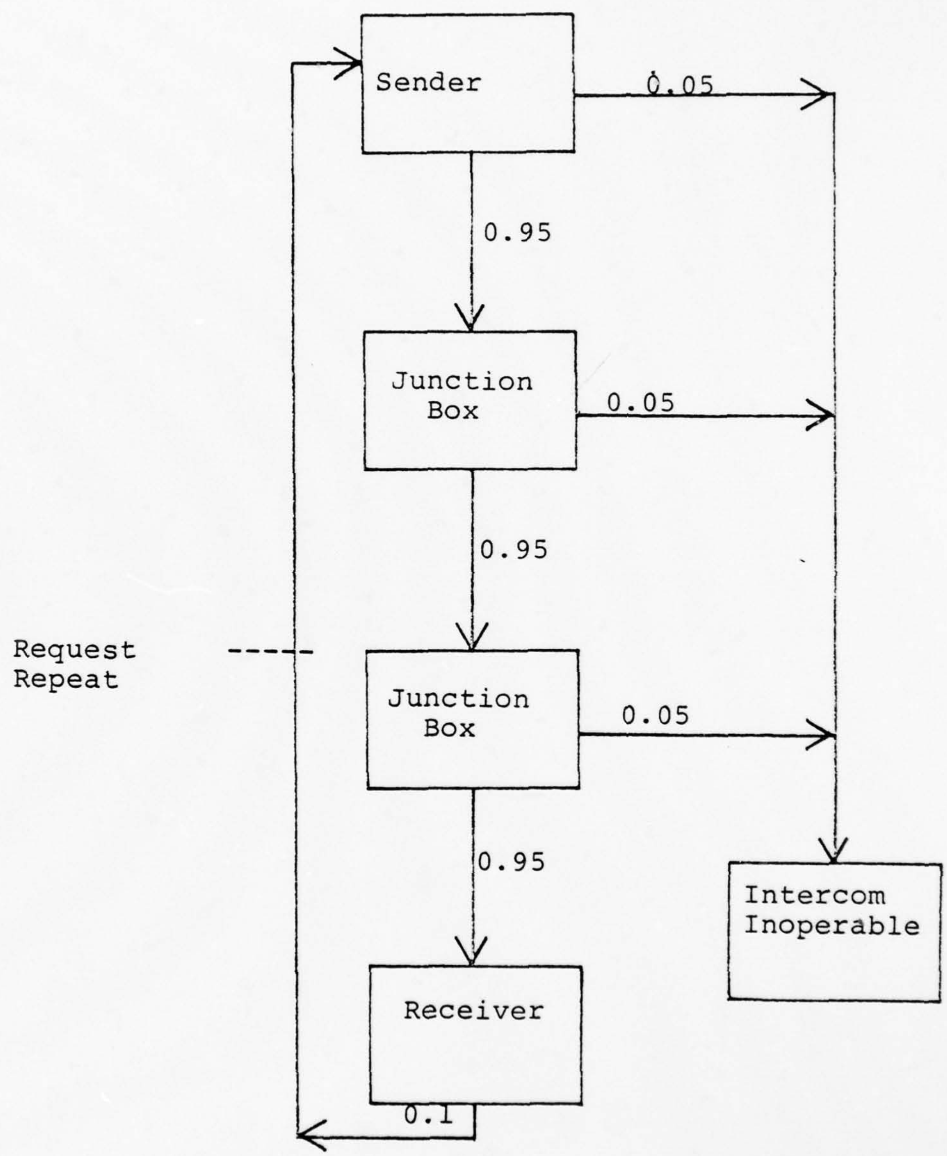

Figure 7

Figure 8 shows the network and the probability of failure parameters used in the simulation. The analytic solution to the system's reliability is

Antenna 1	(0.9)x(0.9) = 0.81
	plus
Antenna 2	(0.19)x(0.95)x(0.995) = 0.179

(0.995 is the reliability of receivers A and B)

This yields a 0.9895 probability of reaching the crew chief who understands 90 percent of all messages received. This results in a total system reliability of 0.940025. The result of simulating one message travelling through the network and all of its possible branches gave an estimate of system reliability of 0.939. Using a message length of uniform distribution between 8.0 and 12.0 seconds, the simulation estimated an average of 31.58 seconds, with variance 10.19, to get a message from a sender to the crew chief. Again a reliability of 0.9 of understanding a radio transmission was an input parameter value (see Figure 8).

C. WAVE NETWORK RESULTS

The network of the ten vehicle wave was simulated for the LVTP7 tractor and for the LVA. The results of each vehicle's sensitivity to parameter value changes are shown in Figures 9 thru 16. Note that the measure of

INTERVEHICLE COMMUNICATION
SIMULATION NETWORK

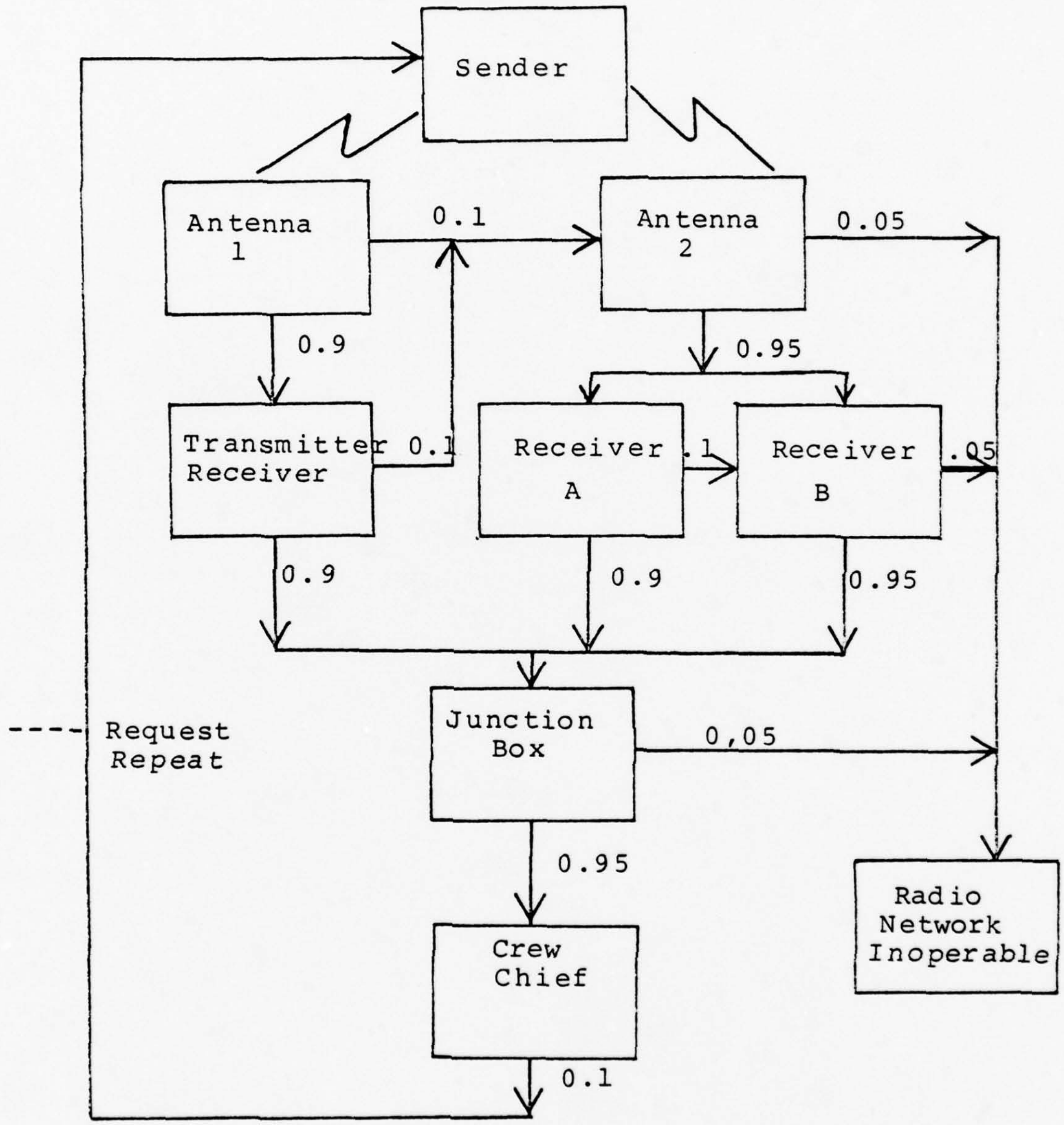

Figure 8

effectiveness used in the parameter sensitivity study was the probability the obstacle was avoided. This probability is a direct reflection of the ability of the wave not only to detect the obstacle, but also to communicate, if necessary, to the endangered vehicles. Then sufficient time for corrective actions, maneuver time, must be available for the endangered vehicle if the obstacle was to be avoided. It was assumed in these simulations that the obstacle was stationary and the closing velocity of the obstacle was solely a function of the speed of the wave.

Figure 9 thru 16 each list the specific parameter values used in each simulation. Vehicle spacing and maximum detection range are measured in meters. Wave speed is measured in miles per hour. The probability of detection, Pdet, is in terms of the probability of detection at the defined maximum detection range.

It is important to remember that all results presented must be examined for trends only. The significance of any particular result (data point) is confined to the assumptions and scope of the model. Linear interpolations were constructed between data points to highlight the trends of the simulation results.

1. LVTP7 Parameter Sensitivity

Figures 9 thru 12 present graphically the results of the simulations for parameter sensitivity of the ten tractor

wave. Changes in detection sector angle (Figure 9), maximum detection range (Figures 10 and 11), and vehicle spacing (Figure 12) were simulated individually. One general trend is noted, the faster the wave moves the lower the probability of avoiding the obstacle. One deviation from this trend is found in Figure 10. This deviation can be attributed to the inherent variability of simulation estimates. The results shown in Figures 9 thru 12 echo the standard operating practices of the LVTP7 tractor wave during waterborne operations. That is, when visibility is a problem (i.e. detection capability decreased) the wave formation is slowed and the vehicle spacing tightened. This 'logical' observation tends to partially validate the model.

2. <u>LVA Parameter Sensitivity</u>

The modeling of the proposed vehicle, LVA, involved three changes to the model of the LVTP7 wave. First, it was necessary to increase the speed of the ten vehicle wave. Next the detection time was shortened, due to the higher speed, and the maneuver time was examined as a parameter of significance. Figures 13 thru 16 display the results of the network simulations performed for the LVA wave, using four different sets of parameters values.

The trend found in the results of the LVTP7 wave simulation is even more noticeable for the LVA simulation. That is, the higher the speed of the wave the lower the

LVTP7 WAVE PARAMETER SENSITIVITY
VARYING DETECTION SECTOR ANGLE

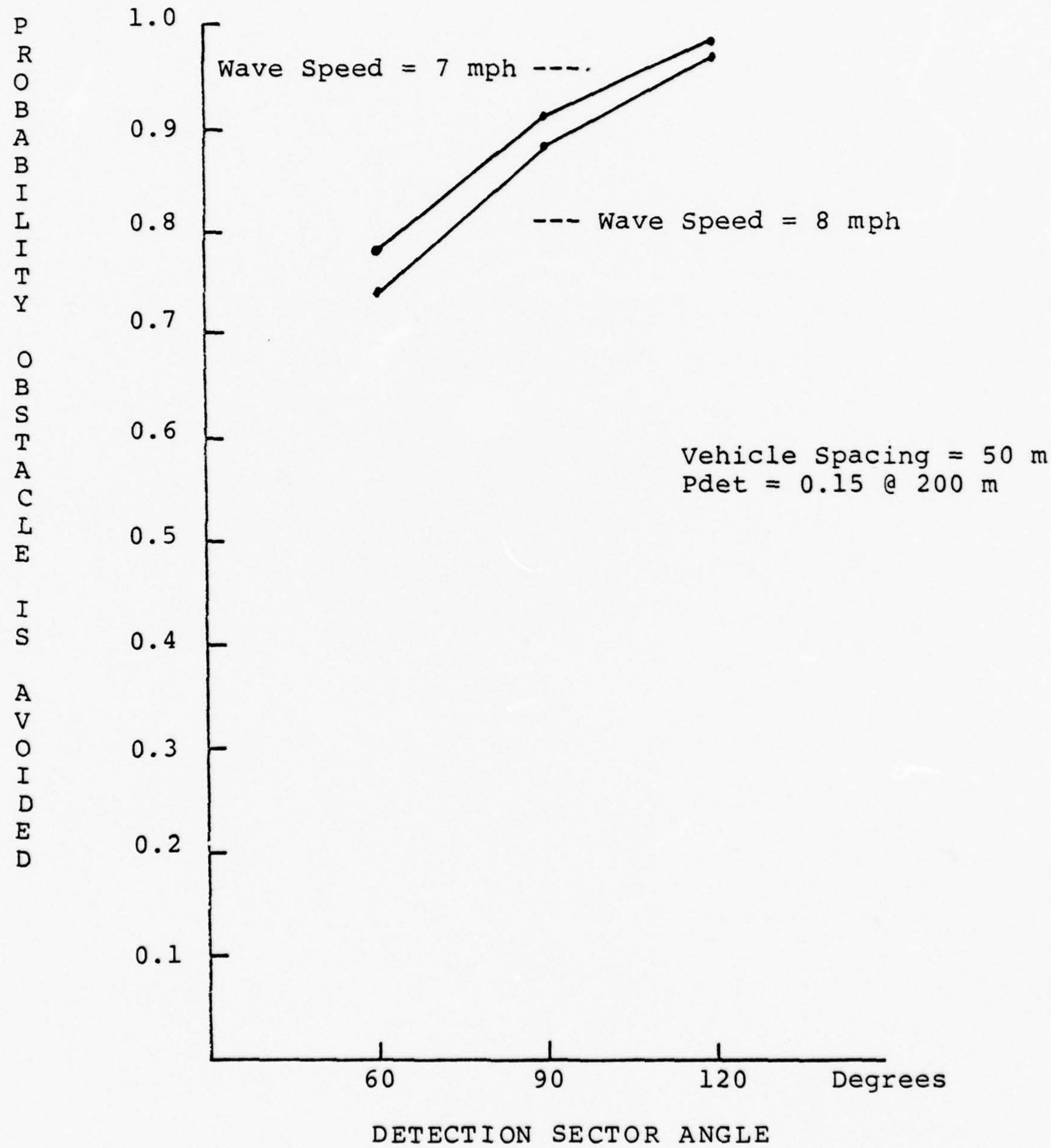

Figure 9

LVTP7 WAVE PARAMETER SENSITIVITY
VARYING MAXIMUM DETECTION RANGE

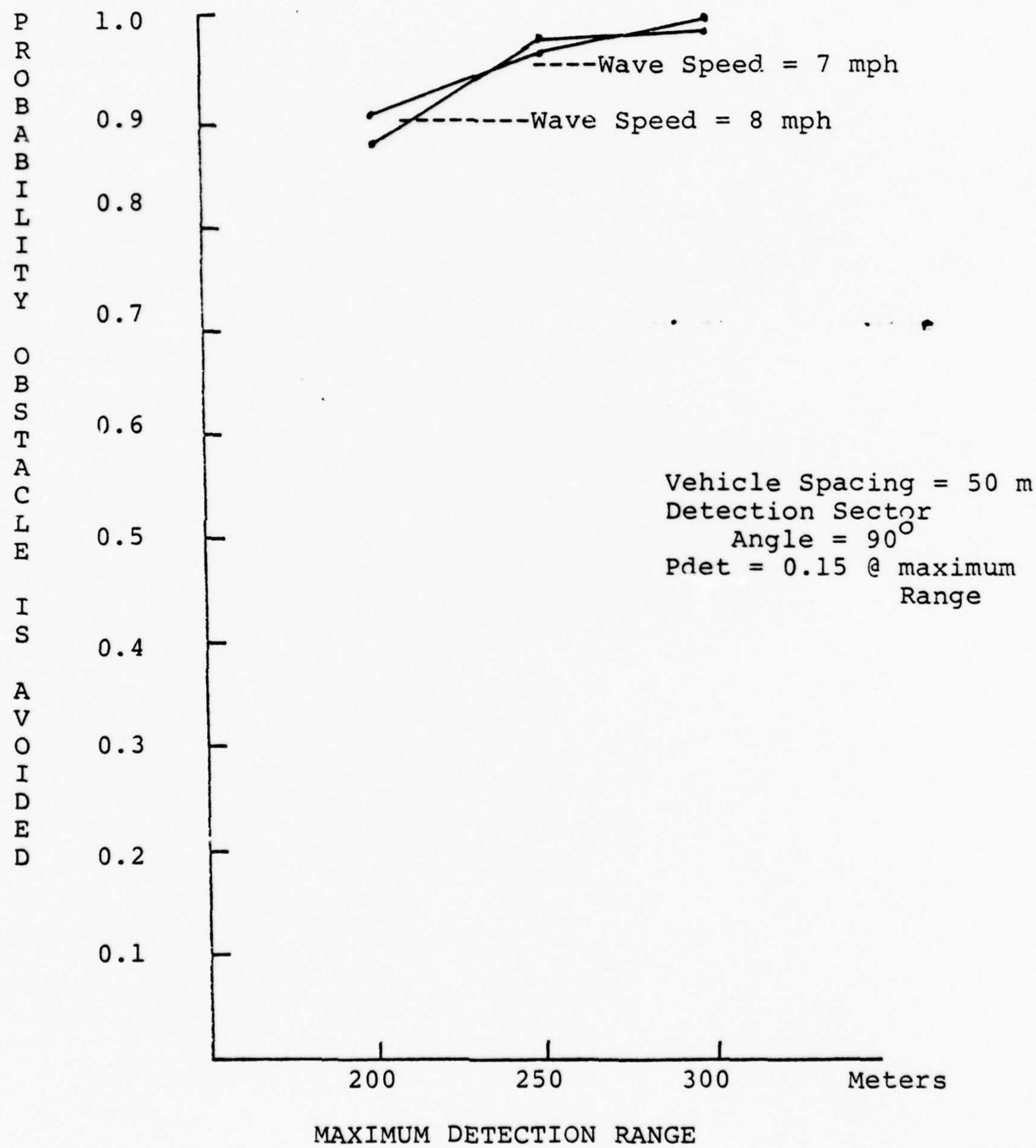

Figure 10

LVTP7 WAVE PARAMETER SENSITIVITY
VARYING INITIAL DETECTION RANGE

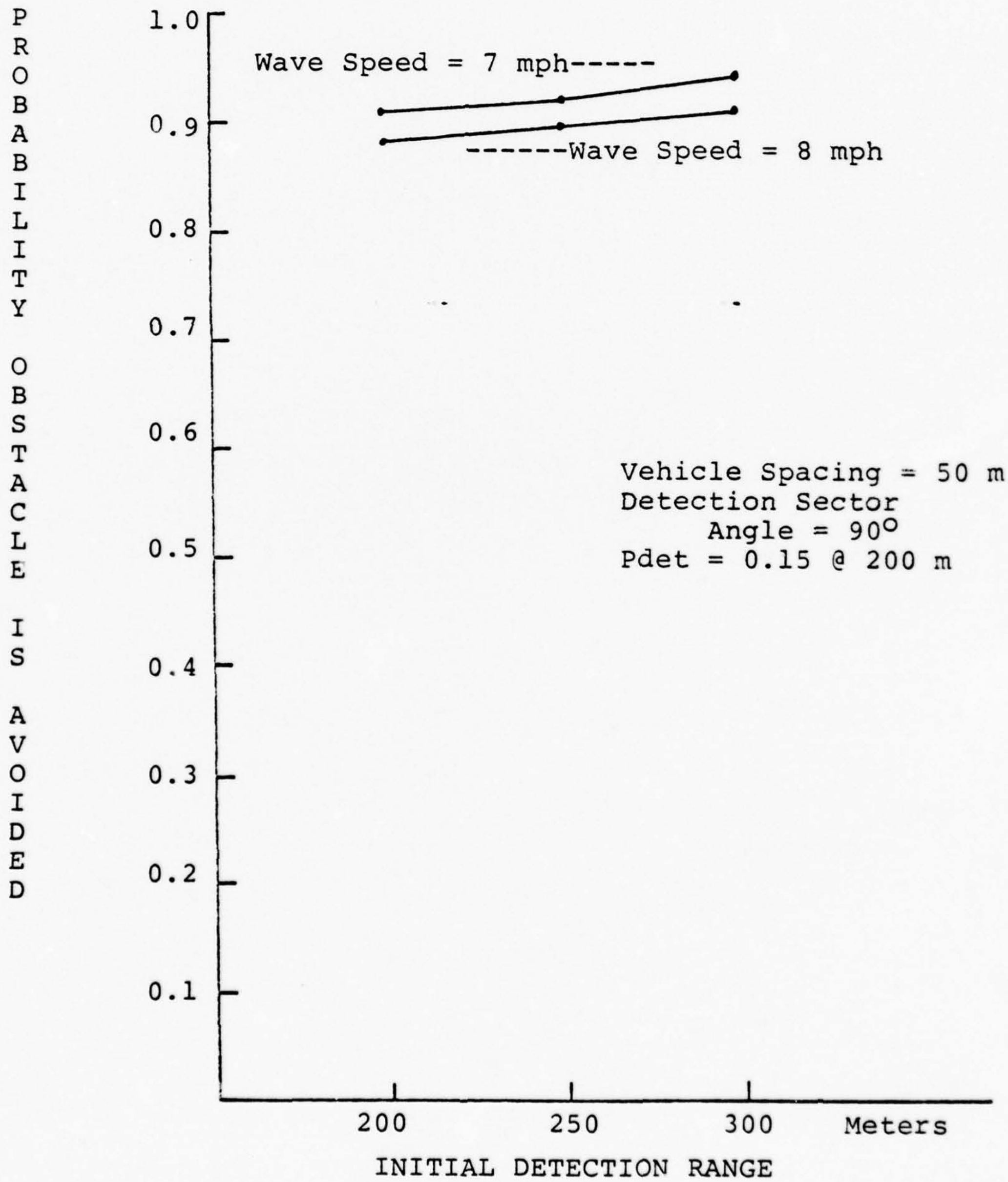

Figure 11

LVTP7 WAVE PARAMETER SENSITIVITY
VARYING VEHICLE SPACING

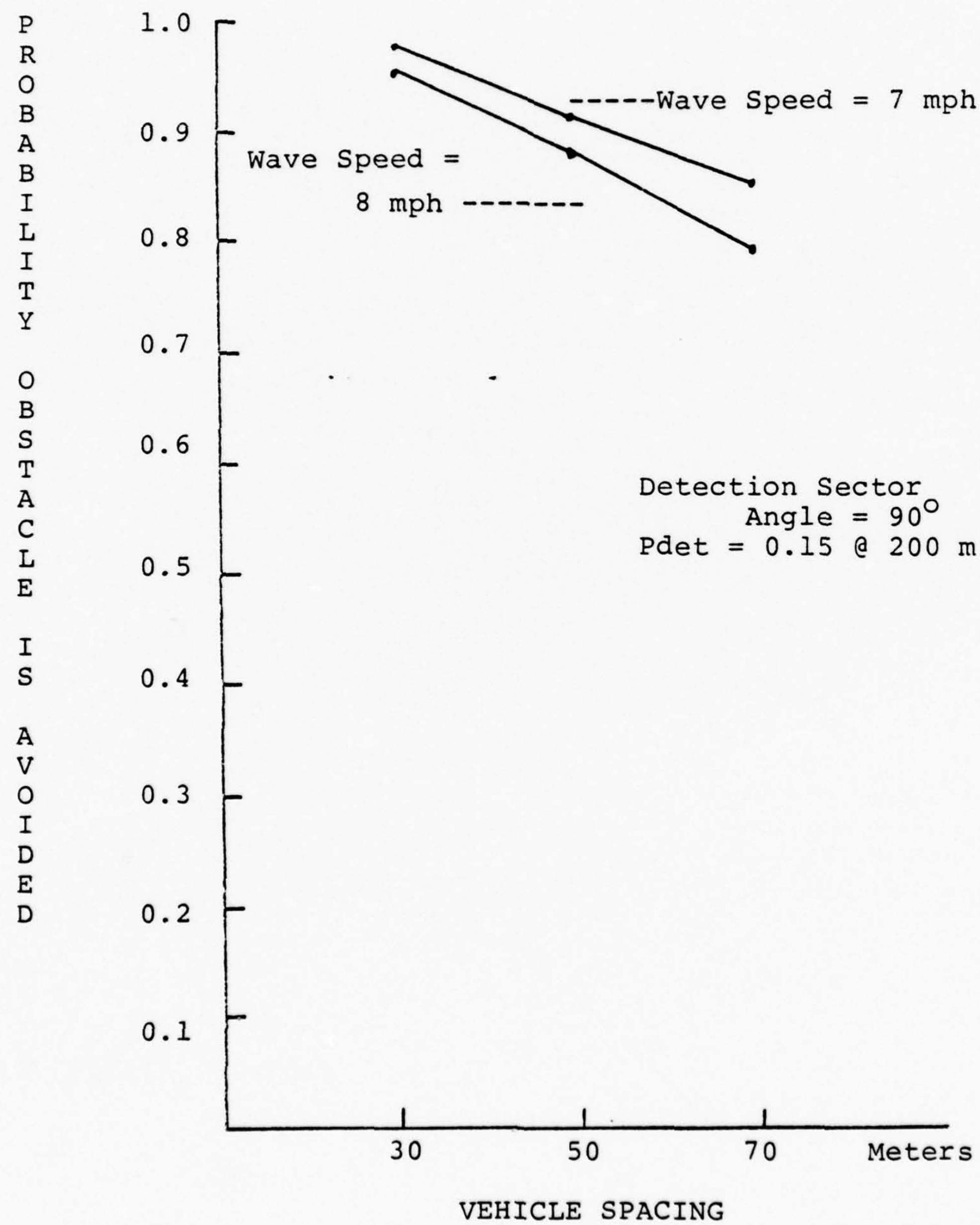

Figure 12

probability the obstacle is avoided. Figures 13 thru 16 also indicate that at maximum detection ranges under 250 meters there is much more sensitivity of the probability of the obstacle being avoided with the higher speed.

Especially in the case of the LVA, significance cannot be attached to any single data point except within the strict limitations of the model, since the LVA was modeled as an LVTP7 tractor with a higher speed in the water. Also, the speed differential between the LVA and the LVTP7, does not seem to explain the observed difference in magnitude of the simulation results. The difference in magnitude appears to be larger than the proportional difference in the two vehicles' speed.

It is apparent from the simulation results of the LVA wave, that there is a need for the LVA to have enhanced detection capability. The results shown in Figures 9 thru 16 suggest possible ways to enhance detection capability and obstacle avoidance. First, by decreasing the vehicle spacing the wave's ability to avoid obstacles increases. Next, an alternate communication means must be available as a standby for radio communication within the wave. Such an alternate communication means was exercised in the model for the LVA wave, but the actual system to be used is unknown. The LVA wave must also use its speed of advance to best accomplish the mission, but also offer the

LVA WAVE PARAMETER SENSITIVITY
PARAMETER SET 1

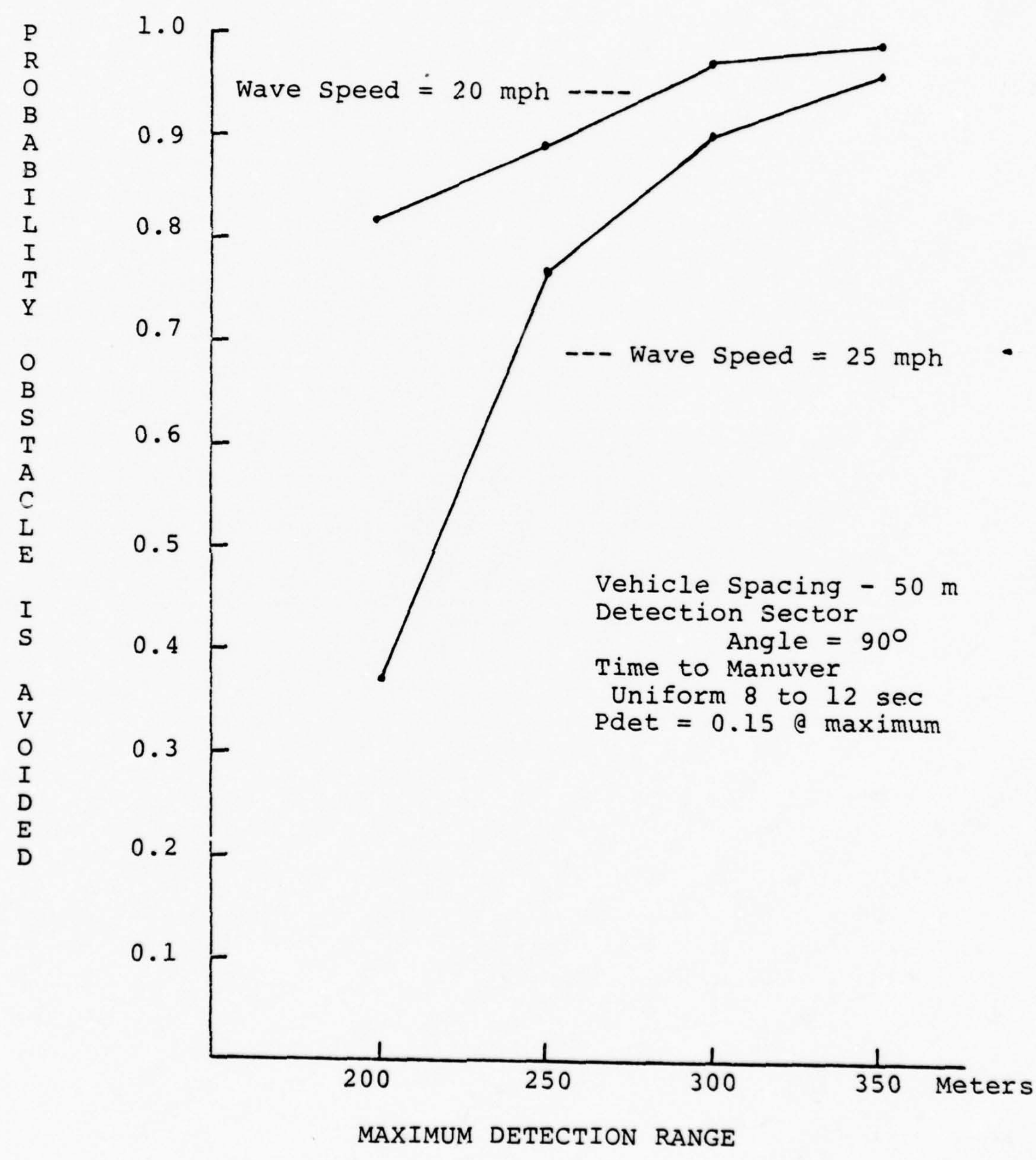

Figure 13

LVA WAVE PARAMETER SENSITIVITY
PARAMETER SET 2

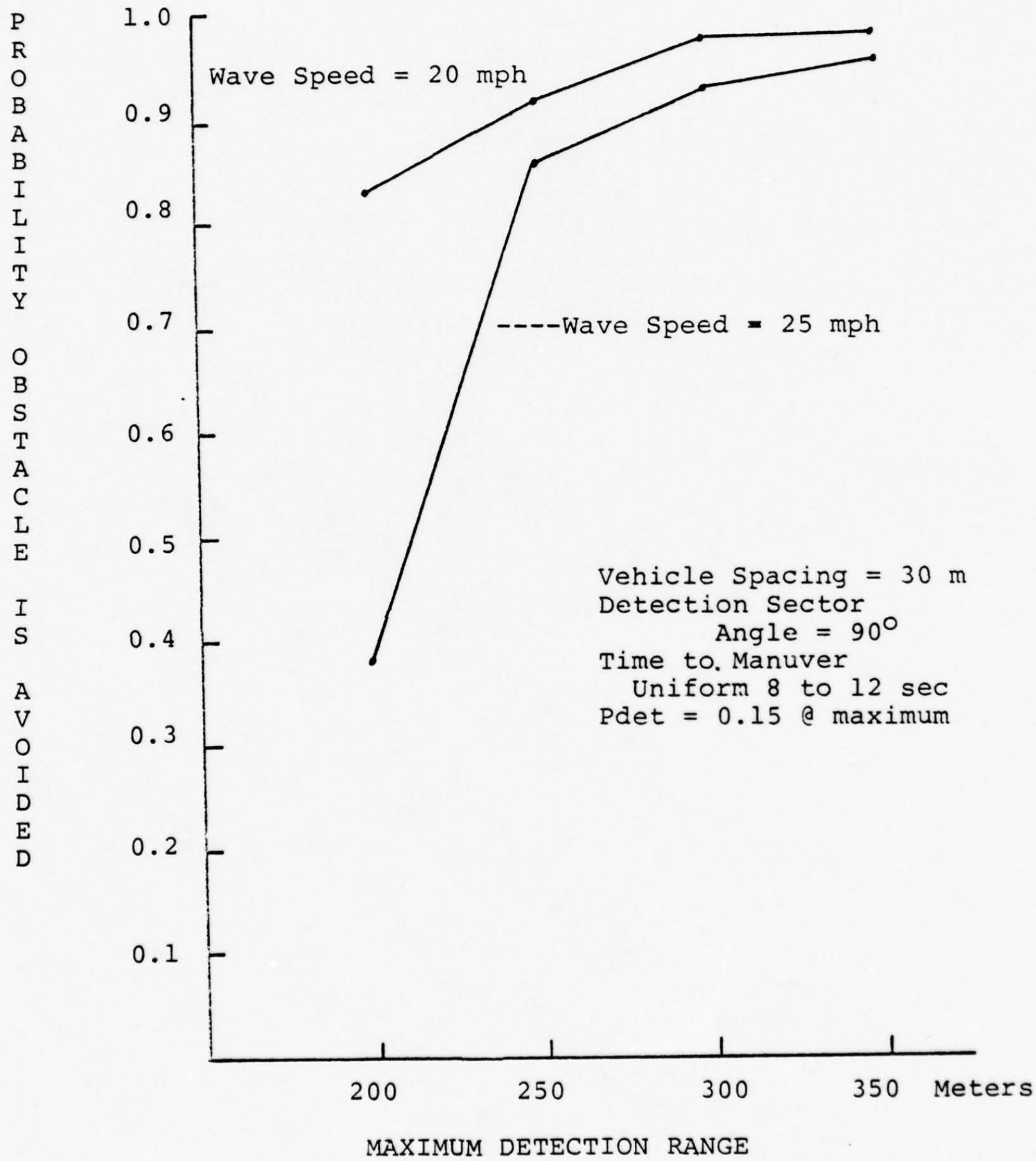

Figure 14

LVA WAVE PARAMETER SENSITIVITY
PARAMETER SET 3

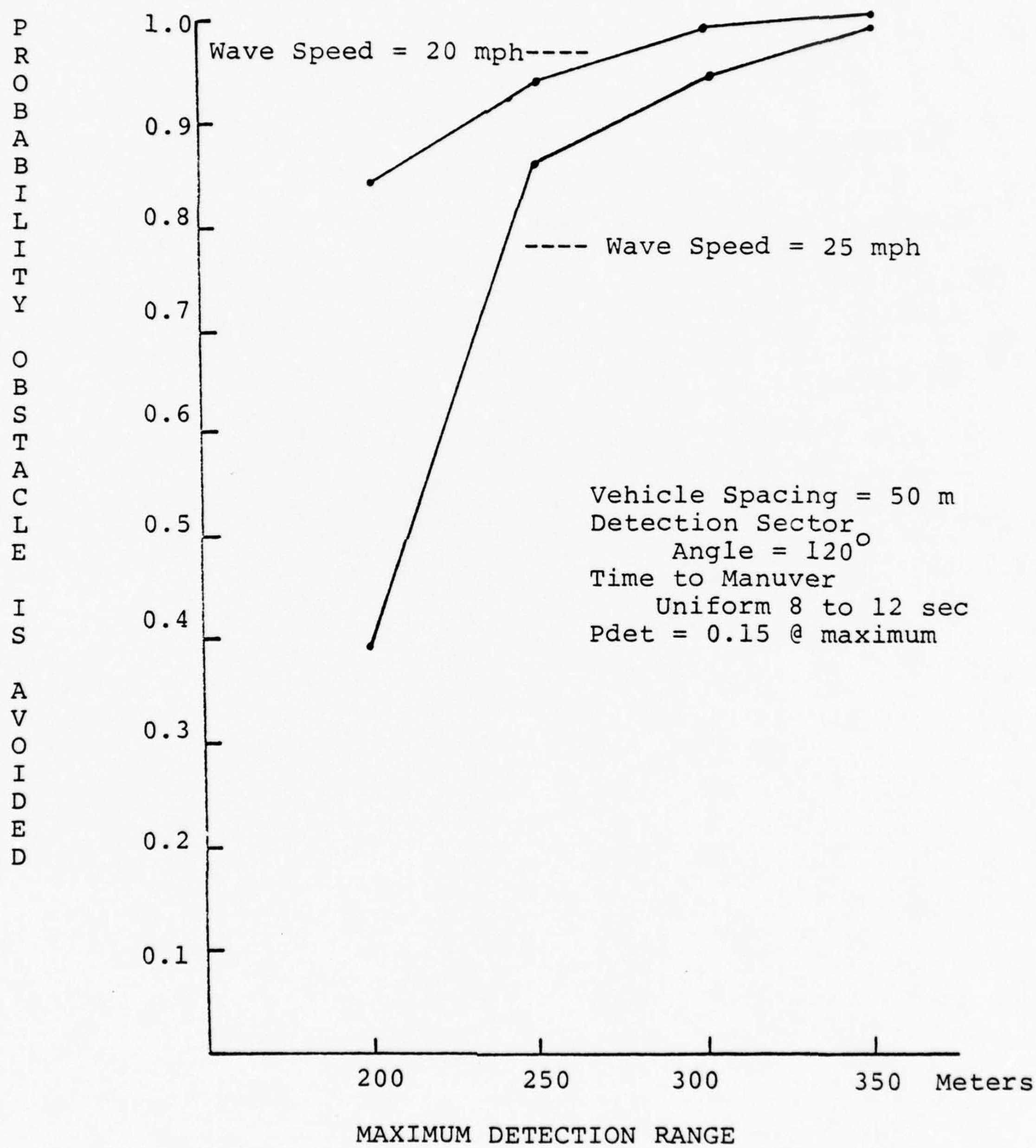

Figure 15

LVA WAVE PARAMETER SENSITIVITY
PARAMETER SET 4

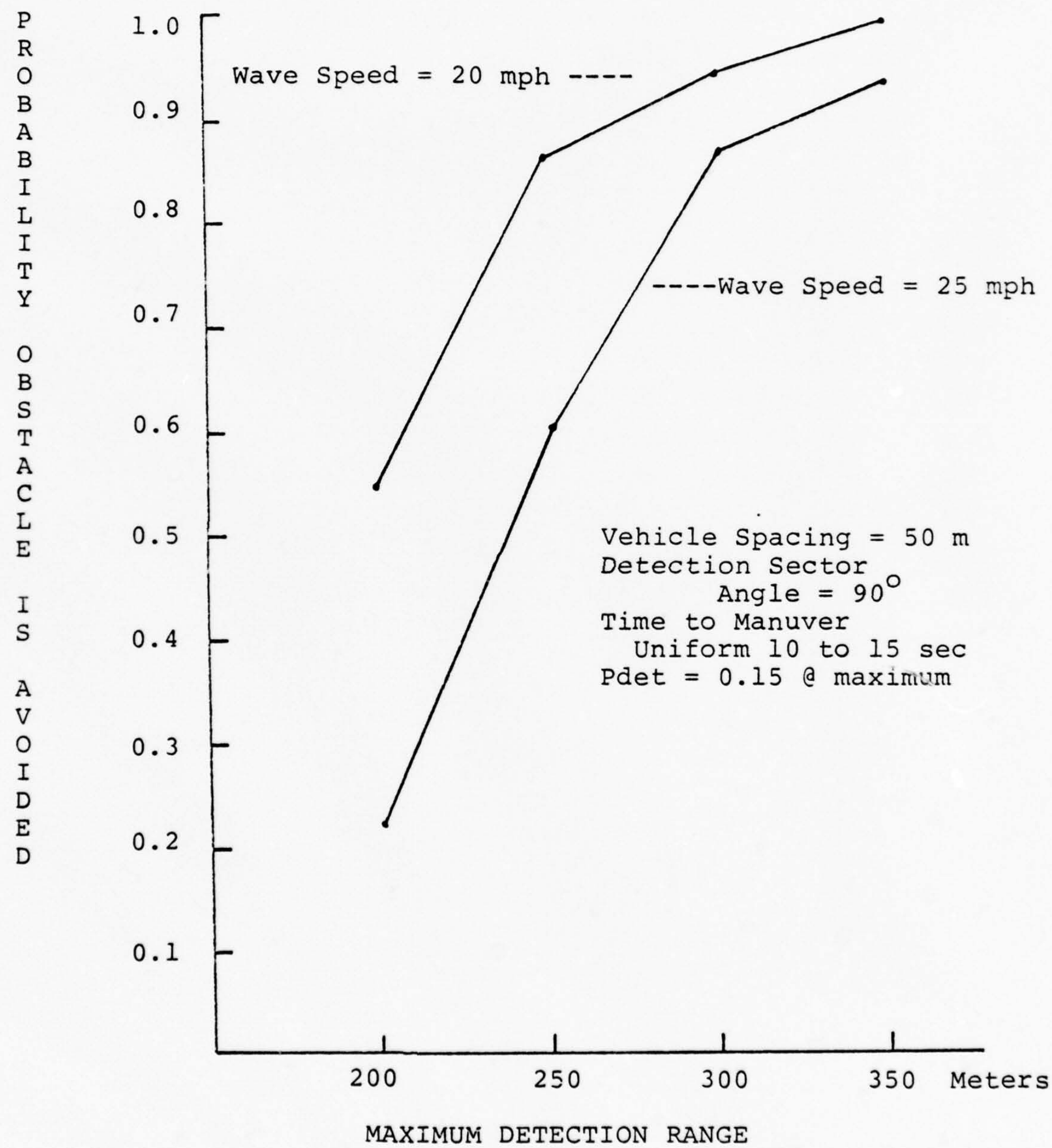

Figure 16

wave the most opportunity to detect and avoid obstacles. The ability of the LVA vehicle crews to increase or decrease their detection sectors is unknown as of now. Also, the use of optical or other navigational aids is not known. The increased vulnerability to obstacles of the LVA wave, due to its speed, is apparent, but, as mentioned above, the solution to the problem may be found in tactical employment of the LVA and not solely in development of new detection devices.

IV. FLEXIBILITY OF THE MODEL

The flexibility of the basic model is examined in this chapter in two ways, modifications of the basic model and possible extensions of the model. Simulations were run for the modifications explained below. The possible extensions of the model are discussed as a guide to future model use.

A. MODEL MODIFICATIONS

Three modifications to the basic model were developed and simulated. In the first modification, the three networks were combined to form a detailed network of the wave. In the second modification an environment which allowed no radio communication was simulated. Finally, in the third modification the three basic networks were chained together. The simulation results of the three individual networks formed the links of the chain. These results from one network were used as the input parameter values of the next network in the chain.

1. Detailed Communication Network

In the first modification, the intervehicle communication network (Figure 5) and the wave network (Figure 6) were combined to give a more detailed communication portion to the wave network. This detailed communication network for the wave allows the user to input the

reliability of all communications equipment in the system. The simulation of this network produces a trace of message traffic thru the entire command, control, and communications system. Such a degree of resolution may be required to evaluate the contribution of a particular piece of equipment to the overall ability of the wave to perform.

Simulations were made with the detailed communication network. The results of these simulations were compared with those of the basic wave communication model. For the wave of LVTP7 tractors and the parameter sets examined, the detailed communication network displayed the same trends of parameter sensitivity. However, in all cases the probability of avoiding the obstacle was lower. This can be attributed to a lower overall communication reliability for the radio links when the detailed network was used. Figure 17 shows the difference in magnitude and similarities in the trend of the basic wave network and the detailed communication network.

2. No-Radio Communication

The basic model was also modified by removing the radio communication capability. This modification may represent a hostile electronic warfare environment (jamming) or a radio silence restriction imposed by the command structure of the amphibious wave. This modification forces heavy reliance on the alternate communication means employed. In the case of the present vehicle, the LVTP7 tractor, the

COMPARISON OF SIMULATION RESULTS
BASIC AND DETAILED COMMUNICATION NETWORKS

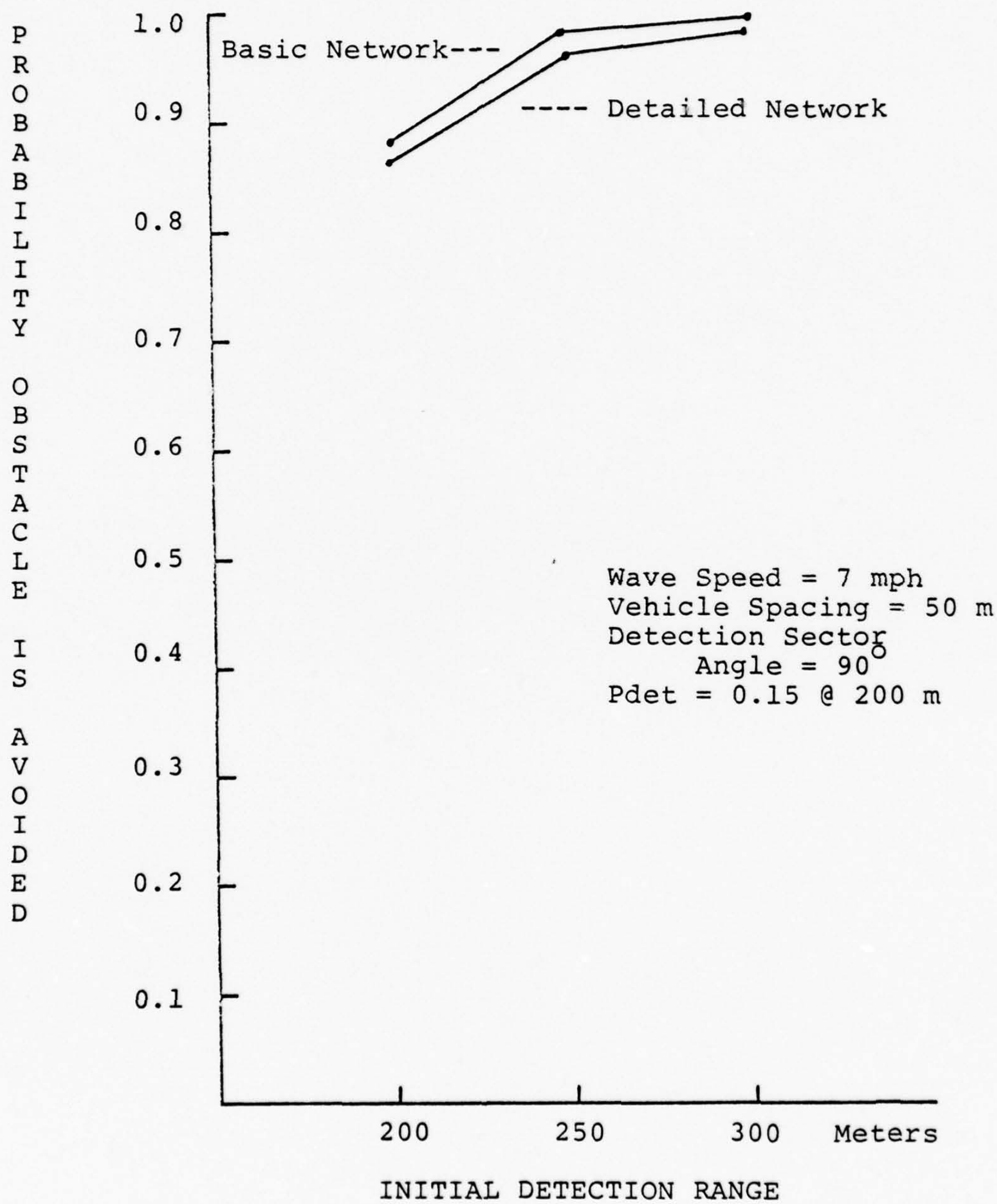

Figure 17

alternate communication means consists of arm and hand signals relayed from vehicle to vehicle in the wave.

The modification to the basic wave communication network was to use the alternate communication links between nodes at all times. The simulation of this modified network used a length of message of 10 to 30 seconds. As in the previous simulations the chance of understanding a transmitted message was input to be 90 percent. Again, one thousand replications of the network were simulated. The results of this simulation, when compared to results of the basic wave network, all other parameter values held constant, showed the no-radio communication network to produce a higher probability of avoiding the obstacle. The two results were 0.926 for the no-radio communication network and 0.914 for the basic wave network. This difference can be attributed to the single communication circuit of the alternate communication means, which is always operable.

3. Chained Networks

The final modification of the basic model was to chain the three basic networks together in an output-to-input chain. Figure 18 shows the arrangement of the three networks in the chain. It can be seen in Figure 18 how one network's simulation results becomes part of the input parameter values of the next network. This chained network simulation is attractive when limited computer resources

CHAINED NETWORKS SIMULATION LAYOUT

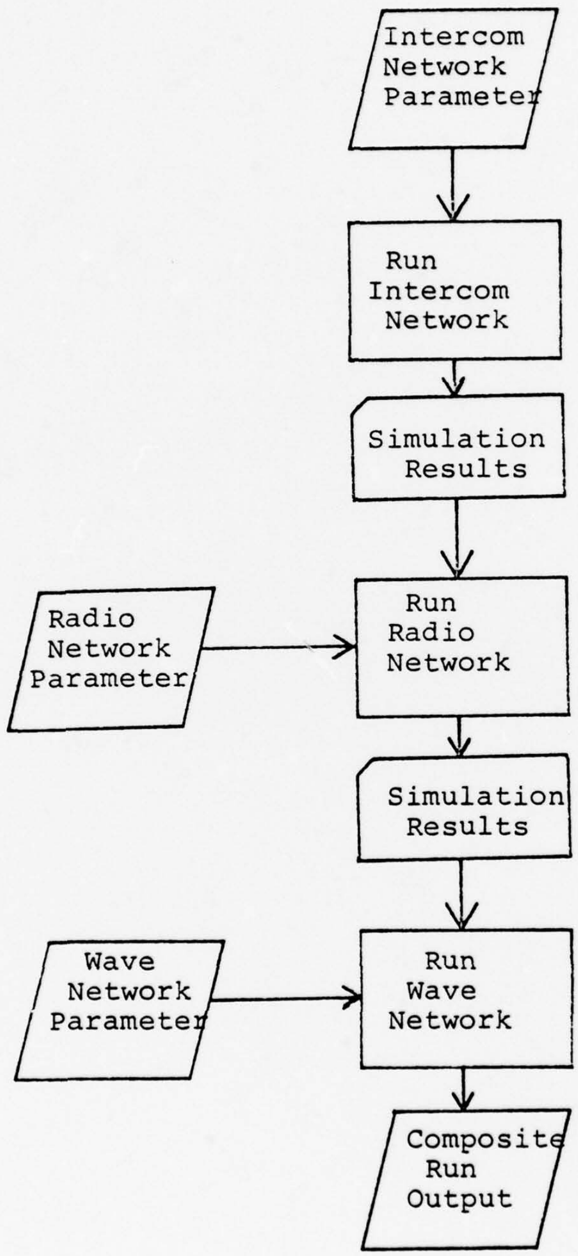

Figure 18

are available. When resources prevent progress through the chain past a certain point, the simulation results at that point can be held for input to the next point in the chain when feasible.

The chained network simulation also allows intermediate results to be checked for reasonableness. Once one network has been simulated the results can be validated prior to proceeding farther down the chain. The final result of the chained network simulation is a detailed communication network with a high degree of resolution, since all three networks were used.

B. EXTENSIONS OF THE MODEL

The modifications described above were performed to show the ability of the model to adjust to different user requirements. Other modifications are possible, but due to limited time and operational data they were not examined in this thesis. Nevertheless, they are outlined below to point out possible future studies using the basic model.

The scope of the model could be extended to include more than one wave. The communication between waves and the associated naval vessels or aircraft could be incorporated in the model. The basic formation of the wave could be changed from the on-line formation to any other tactical arrangement of vehicles.

The method of exercising the model may be changed. Instead of obstacle avoidance, perhaps vehicle damage or casualties would generate the requirement for exercising the communication links of the wave. In that case a new measure of effectiveness would need to be developed to measure the ability of the communication networks to perform.

The parameter values of the model could be modified to reflect individuality of each vehicle. For example, different vehicles in the wave would have different detection sector angles. A study could then be done to find optimal mixes of detection sectors. The benefits of employing optical devices to aid detection could also be examined using the basic model with appropriate modifications to the detection model.

V. CONCLUSIONS

At the outset of this thesis the goal was to develop a model of the command, control and communication system in the ship-to-shore movement of an amphibious wave and to exercise the model to determine those parameters to which the model was sensitive. An additional goal in this thesis was to examine parameter sensitivity to changes in vehicle characteristics. The model proved capable of accepting parameter values for the proposed LVA based on present design specifications. Then through simulation the results were found that gave indications of possible problem areas for the LVA. Of course, the exact values of the results are perhaps not meaningful, but the trends displayed in Figures 13 thru 16 indicate the need for the LVA to have an enhanced detection capability to compliment its increased speed capability.

Within the limitations of time and available data, a simple and flexible model was developed to meet the expectations. To complete the examination of the model, the advantages and disadvantages of the model are discussed below and a final note to the prospective model user is included.

A. ADVANTAGES OF THE MODEL

The network simulations used in the model have several advantages in examining parameter sensitivity. The networks are transparent to the observer and the observer can see the system in as much detail as he desires. All personnel, pieces of equipment and states that the command structure occupies in time are represented in the networks. Networks are inherently flexible and this was shown in the modifications explained in Chapter IV.

The simulation model allows us, the user, to replicate real-world exercises. The simulation of each network separately or the simulation of combined networks offers a choice to the model user, depending upon his needs, of what degree of resolution of the system to compare to the real world. Simulation also offers the model user the ability to change any parameter value and get immediate results for comparison to real data for validation.

The model presented in this thesis is simple, with few assumptions. This simplicity makes it easy to validate the model. The model also may become a base from which a more complex model may be built.

B. DISADVANTAGES OF THE MODEL

The main disadvantage of the model is that there is no exact answer produced for interpretation. All simulation results are sensitive to input parameter values and the

outcomes of simulating random events. The results of the model must be examined for trends only. Significance can not be placed on the magnitude of any one simulation result.

The dependence on automated network simulation (computer simulation) is another disadvantage. The memory space (core size) required to store and solve the networks is expensive. To stabilize results, a large number of replications of the simulation is required. This computer time usage is also expensive. In short, to gain more reliable results, of large networks, large expenditures of computer time and core space are necessary.

C. DATA FOR MODEL VALIDATION

Once the prospective model user has decided to use the model presented he must provide the data, input parameter values, to validate the model. Then, if the model is applicable, run the model with the desired input parameter values. Many different input parameters were discussed in this examination of the amphibious assault wave. The required type, form, and quantity of input parameters are discussed below.

Three basic types of data are required by the model. Reliability information of components, communication means and their time to transmit messages, and a vehicle's maneuvering characteristics in the waterborne mode must be input. Also, an appropriate detection model must be

incorporated if the present model is not satisfactory. The appropriate location for each parameter value is evident in the networks presented. Appendix A, the sample Q-GERTS simulation program, is well documented as to the location of parameter value inputs.

The form in which the data is accepted depends upon its type. Reliability data should reflect the probability of the component operating for a period of time equal to the mission length. This single number probability can be either manufacturer's specification or field test data. The transmission times for communication by different means and a vehicle's maneuver time can be defined by probability mass distributions or single value estimates. If the available data conforms to known probability mass functions or to any fitted curve, the Q-GERTS algorithms can accept the data by parameterizing the curve.

The quantity of the data will be determined by the prospective model user. The varying of parameter values to reflect different scenarios is one determining factor, since only one set of parameter values is reflected in a single simulation result. Accuracy of the input parameter values also affects the quantity of data needed. To refine the estimates of the input parameter values, a larger data base is normally required.

D. FINAL NOTE TO THE PROSPECTIVE MODEL USER

The purpose of this thesis was to develope a basic, flexible and solvable model of the ship-to-shore phase of an amphibious assault. A model was developed, exercised and presented with the results discussed. The advantages, disadvantages, modifications and possible extensions of the model were also discussed. The prospective user of this model should take this entire examination into consideration before deciding upon using this model. The decision on whether to use the model or not should be weighed with other available alternatives which provide the same scope and purpose.

APPENDIX A

SAMPLE Q-GERTS SIMULATION PROGRAM

SIMULATION OF THE WAVE NETWORK

```
C
C
C                    USER INPUT SUBROUTINE
C
C
      SUBROUTINE UI
      COMMON /QVAR/ NDE,NFTBU(100),NREL(100),NRELP(100),
     1NREL2(100),NRUN,NRUNS,NTC(100),PARAM(100,4),TBEG,TNOW
      COMMON/SPECS/DIST,ISEED,POSIT,SPEED,SP,THEATA,LANE
      IF (NRUN.EQ.1) ISEED=1993
C
C     INPUT DATA
C
C     MAXIMUM DETECTION RANGE IN METERS
C
      DIST=200.0
C
C     SPEED OF THE OBSTACLE IN METERS/SECOND
C
      SPEED=3.11
C
C     VEHICLE SPACING IN METERS
C
      SP=50.0
C
C     SECTOR OF DETECTION IN RADIANS
C
      THEATA=1.57
C
C     GENERATE THE OBSTACLE
C
      CALL GGUB(ISEED,1,U)
C
C     POSITION OF THE OBSTACLE FROM THE LEFT BOUNDARY
C
      POSIT=(10.0*SP)*U
      LANE=INT(POSIT/SP)+1
      RETURN
      END


C
C
C                    USER FUNCTION SUBROUTINE
C
C
      SUBROUTINE UF(IFN)
      COMMON /QVAR/ NDE,NFTBU(100),NREL(100),NRELP(100),
     1NREL2(100),NRUN,NRUNS,NTC(100),PARAM(100,4),TBEG,TNOW
      COMMON/SPECS/DIST,ISEED,POSIT,SPEED,SP,THEATA,LANE
      REAL*4 LLIM
      UF=0.0
      GO TO (1,2,3),IFN
C
C     USER FUNCTION ONE
C      LOCATE PRESENT DISTANCE OF OBSTACLE FROM THE WAVE
C
    1 DNOW=DIST-(TNOW*SPEED)-1.0
      LLIM=SP*(GATRB(1)+0.5)-(DNOW*TAN(THEATA/2.0))
      RLIM=SP*(GATRB(1)+0.5)+(DNOW*TAN(THEATA/2.0))
```

```
C
C     CETERMINE IF THE OBSTACLE IS IN THE AREA OF DETECTION
C
      IF (POSIT.GE.LLIM.AND.POSIT.LE.RLIM) GO TO 11
      UF=0.0
      RETURN
C
C     DETERMINE IF THE OBSTACLE IS DETECTED
C
   11 A=ALOG(.85)*DIST**2
      PDET=1.0-EXP(A/DNCW**2)
      CALL GGLB(ISEED,1,U)
      IF (PDET.GE.U) GO TO 12
      UF=0.0
      RETURN
   12 UF=1.0
      RETURN
C
C     USER FUNCTION TWO
C     IS THE OBSTACLE IN THIS LANE
C
 2    IF (GATRB(1).EQ.LANE) GO TO 21
      UF=0.0
      RETURN
   21 UF=1.0
      RETURN
C
C     USER FUNCTION THREE
C     DETERMINE TIME FOR THE OBSTACLE TO REACH THE WAVE
C
 3    UF=DIST/SPEED
      RETURN
      END
```

*** NETWORK DATA CARDS ***

```
GEN,MARK-COSTA,WAVE-NET,2,25,1978,1,3,1,,1000,,,6,750*
                        *** NODES ***
SOU,1,0,1,A*  VEHICLE 1 SEARCHES DETECTION SECTOR
SOU,2,0,1,A*  VEHICLE 2 SEARCHES DETECTION SECTOR
SOU,3,0,1,A*  VEHICLE 3 SEARCHES DETECTION SECTOR
SOU,4,0,1,A*  VEHICLE 4 SEARCHES DETECTION SECTOR
SOU,5,0,1,A*  VEHICLE 5 SEARCHES DETECTION SECTOR
SOU,6,0,1,A*  VEHICLE 6 SEARCHES DETECTION SECTOR
SOU,7,0,1,A*  VEHICLE 7 SEARCHES DETECTION SECTOR
SOU,8,0,1,A*  VEHICLE 8 SEARCHES DETECTION SECTOR
SOU,9,0,1,A*  VEHICLE 9 SEARCHES DETECTION SECTOR
SOU,10,0,1,A* VEHICLE 10 SEARCHES DETECTION SECTOR
REG,11,1,1,D* DETECTION HAS BEEN MADE
REG,12,1,1,A*  IS THE OBSTACLE IN MY LANE?
REG,13,1,,D*  THE OBSTACLE IS IN MY LANE
REG,20,1,1,P* IS MY RADIO OPERATIONAL?
```

```
ACT,5,11,CC,0,15,,,A2.EC.1.0*  DETECTION MADE
ACT,6,11,CO,0,16,,,A2.EC.1.C*  DETECTION MADE
ACT,7,11,CO,0,17,,,A2.EC.1.0*  DETECTION MADE
ACT,8,11,CC,0,18,,,A2.EC.1.0*  DETECTION MADE
ACT,9,11,CO,0,19,,,A2.EQ.1.0*  DETECTION MADE
ACT,10,11,CO,0,20,,,A2.EQ.1.0* DETECTION MADE
ACT,11,12,CO,C,21*
ACT,12,13,CO,C,22,,,A3.EQ.1.0* OBSTACLE IS IN MY LANE
ACT,12,20,CC,0,23,,,A3.EC.0.0* OBSTACLE IS IN ANOTHER LANE
ACT,13,98,NC,2,24*      TIME TO MANEUVER A VEHICLE
ACT,20,21,NC,3,25,,0.9*  LENGTH OF MESSAGE TRANSMITTED
ACT,20,30,CO,0,26,,0.1*  MY RADIO IS DOWN
ACT,21,22,CO,0,27,,0.9*  HIS RADIO IS OPERATIONAL
ACT,21,30,UN,4,28,,0.1*  HIS RADIO IS DOWN
ACT,22,23,CO,0,29,,0.1*  HE DOES NOT UNDERSTAND
ACT,22,99,NO,2,30,,0.9*  TIME TO MANEUVER A VEHICLE
ACT,23,20,UN,4,31*      REQUEST REPEAT OF INSTUCTION
ACT,30,31,NC,3,32*   TIME TO TRANSMIT MESSAGE
ACT,31,99,NC,2,33,,0.9*  TIME TO MANEUVER A VEHICLE
ACT,31,30,UN,4,34,,0.1*  REQUEST REPEAT OF INSTRUCTION
ACT,80,81,UF,3,35*      TIME FOR OBSTACLE TO REACH THE WAVE
ACT,11,97,CO,0,36*

                    *** PARAMETERS ***
PAR,1,30,10,120*        TIME BETWEEN GLIMPSES
PAR,2,11.6,10,13,1.2*  TIME TO MANEUVER A VEHICLE
PAR,3,15,10,30,4*       LENGTH OF RADIO MESSAGE TRANSMITTED
PAR,4,,5,10*   LENGTH OF MESSAGE BY ALTERNATE MEANS
```

```
REG,21,1,1,P* IS HIS RADIO OPERATIONAL?
REG,22,1,1,P* ARE HIS RADIC CIRCUITS OPERATIONAL?
REG,23,1,1,D* HIS RADIO IS DOWN
REG,30,1,1,D* CCMMUNICATE BY ALTERNATE MEANS
REG,31,1,1,P* IS THE MESSAGE UNCERSTOCC?
SOU,80,C,,D*  THE CBSTACLE BEGINS TO APPRCACH THE WAVE
SIN,81/TCC-LATE,1,,D*  THE OBSTACLE REACHES THE WAVE
STA,97/DETECT,1,,D*    THE CBSTACLE IS CETECTED TIME
SIN,98/CWN-LANE,1,,D*  THE OBSTACLE IS AVCIDED IN MY LANE
SIN,99/CCM-MADE,1,,D*  ENCANGERED VEHICLE CONTACTEC IN TIME
VAS,1,1,CO,1,2,UF,1*
VAS,2,1,CO,2,2,UF,1*
VAS,3,1,CO,3,2,UF,1*
VAS,4,1,CO,4,2,UF,1*
VAS,5,1,CO,5,2,UF,1*
VAS,6,1,CO,6,2,UF,1*
VAS,7,1,CO,7,2,UF,1*
VAS,8,1,CC,8,2,UF,1*
VAS,9,1,CO,9,2,UF,1*
VAS,10,1,CO,10,2,UF,1*
VAS,12,3,UF,2*
                    *** ACTIVITIES ***
ACT,1,1,EX,1,1,,,A2.EQ.0.0*      TIME TO NEXT GLIMPSE
ACT,2,2,EX,1,2,,,A2.EQ.0.0*      TIME TC NEXT GLIMPSE
ACT,3,3,EX,1,3,,,A2.EQ.0.0*      TIME TO NEXT GLIMPSE
ACT,4,4,EX,1,4,,,A2.EQ.0.0*      TIME TC NEXT GLIMPSE
ACT,5,5,EX,1,5,,,A2.EQ.0.0*      TIME TC NEXT GLIMPSE
ACT,6,6,EX,1,6,,,A2.EQ.0.0*      TIME TC NEXT GLIMPSE
ACT,7,7,EX,1,7,,,A2.EQ.0.0*      TIME TC NEXT GLIMPSE
ACT,8,8,EX,1,8,,,A2.EQ.0.0*      TIME TC NEXT GLIMPSE
ACT,9,9,EX,1,9,,,A2.EQ.0.0*      TIME TO NEXT GLIMPSE
ACT,10,1C,EX,1,10,,,A2.EC.0.0*   TIME TC NEXT GLIMPSE
ACT,1,11,CC,0,11,,,A2.EC.1.0*    DETECTICN MADE
ACT,2,11,CO,0,12,,,A2.EQ.1.0*    CETECTICN MADE
ACT,3,11,CO,0,13,,,A2.EC.1.0*    CETECTICN MADE
ACT,4,11,CC,0,14,,,A2.EC.1.0*    CETECTICN MADE
```

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